GUJARAT TECHNOLOGICAL UNIVERSITY

PHYSICS OF MOS TRANSISTOR
SUBJECT CODE: 3712605
SEMESTER: I

Type of course: Advanced Semiconductor Active Device Modeling

Prerequisite: Fundamental knowledge of semiconductor and devices, and mathematics

Rationale: Students of ME in VLSI must possess a good understanding of concepts of modeling of MOSFET. Students also must learn about various short channel effects and its modeling. This is one of the foundation courses which are required for designing state-of-art MOSFET based circuits for applications demanding low-power, low-voltage, and high speed.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE(E)	PA (M)	PA (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1	**Semiconductors, Junctions, and MOSFET Overview:** Semiconductors, Conduction, Contact Potentials, *pn* junction, Overview of MOS Transistor	5	12 %
2	**Two-Terminal MOS Structure:** Introduction, Flat-band voltage, Potential and Charge balance, Effect of Gate-Substrate Voltage on Surface Condition, Regions of Inversion and Analysis, Small-Signal Capacitances	8	19 %
3	**Three-Terminal MOS Structure:** Introduction, Contacting the Inversion layer, Body effect, Regions of Inversion and Mathematical Analysis, Study of MOS Structure from "VCB" Control Point of View	6	14 %
4	**Four-Terminal MOS Structure:** Transistor Regions of Operation, General Charge Sheet Models, Strong Inversion, Weak Inversion, Moderate Inversion, Interpolation Models, Source Referenced versus Body Referenced Modeling, Effective Mobility, Temperature Effects, Breakdown, p-channel MOS Transistor, Enhancement-Mode and Depletion-Mode Transistors, Model Parameter Values, Model Accuracy, Model Comparison	10	24 %
5	**Small-Dimension Effects:** Introduction, Channel Length Modulation, Barrier Lowering, Two-Dimensional Charge Sharing, Threshold Voltage, Punch-through, Carrier Velocity Saturation, Hot Carrier Effects, Scaling, Effects of Surface and Drain Series Resistances, Effects due to Thin Oxides and High Doping	8	19 %
6	**MOSFET Modeling for Circuit Simulation:** Introduction, Types of Models, Combining Several Effects into One Physical Model, Parameter Extraction, Accuracy, Properties of Good Models, General Considerations, Benchmark Tests, Nontechnical	5	12 %

	Considerations		
Total		42	

Reference Books:

1. Operation and Modeling of The MOS Transistor, Y. Tsividis
2. S. M. Sze, Physics of Semiconductor Devices, (2e), Wiley Eastern
3. N. D. Arora, MOSFET Models for VLSI Circuit Simulation, Springer-Verlag

Course Outcome:

Students will get sound knowledge in following topics which are required for design of advanced MOSFET circuits.

1. Semiconductor physics.
2. MOS capacitor modeling and effects of frequency on C-V characteristic.
3. MOSFET modeling techniques.
4. Short-channel effects and its modeling.
5. MOSFET parameter measurements.
6. Benchmark tests for MOSFET models

List of Experiments:

1. To obtain I_D – V_{GS} characteristic of n-channel and p-channel MOSFET for different values of V_{DS} and V_{BS}. (180 nm technology)
2. To obtain I_D – V_{DS} characteristic of n-channel and p-channel MOSFET for different values of V_{GS} and V_{BS}. (180 nm technology)
3. To obtain C – V characteristic of p-type substrate MOS capacitor. (180 nm technology)
4. To obtain V_{Tn} as a function of V_{BS} for n-channel MOSFET device and calculate body-bias parameter. (180 nm technology)
5. To obtain V_{Tn} as a function of V_{DS} for n-channel MOSFET device and calculate DIBL parameter. (180 nm technology)
6. To obtain leakage current as a function of V_{DS} for n-channel MOSFET device and calculate subthreshold (SS) parameter. (180 nm technology)
7. To observe CLM effect from I_D – V_{DS} characteristic of n-channel MOSFET device and calculate output resistance. (180 nm technology)
8. To obtain g_m – V_{GS} characteristic of n-channel and p-channel MOSFET for different values of V_{DS} and V_{BS}. Calculate threshold voltage from g_m – V_{GS} characteristic. (180 nm technology)
9. To obtain following parameters for two different technologies (180 nm and 90 nm) and compare them.

a) DIBL
b) SS
c) Output resistance

10. To observe the effect of leakage current, simulate CMOS inverter circuit in 180 nm and 90 nm technology and obtain leakage power dissipation
11. To measure I_D –V_{GS} and I_D - V_{DS} characteristic for n-channel/p-channel MOSFET device. Obtain following parameters:

a) Body-bias parameter
b) DIBL
c) SS
d) Output resistance

Major Equipments:

i. Function Generator
ii. Oscilloscope
iii. Digital Multi-meter
iv. DC Power Supply (0-30 V)

List of Open Source Software/Learning website:

Multisim, PSPice, NGspice (**Open Source Software**)